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*All communications should be addressed to the Editor.*

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## Notices of the Royal Aëronautical Society.

**Obituary.**—We regret to announce the death of Major Bertram Hopkinson, C.M.G., F.R.S., M.Inst.C.E., a Fellow of this Society. Major Hopkinson joined the Society in the present year and was killed in a flying accident near London, on August 26th.

We also regret to announce the death of Lieutenant Francis Graham Reddie, R.A.F., killed on active service in France. Lieutenant Reddie joined the Society in 1917, at the age of 16, as a Student Member.

**The Journal.**—Subscribers are requested to notify any change of address to this office without delay. Several cases of non-delivery of journals have been reported and upon inquiry the cause is always found to be the omission to advise us of removal.

**The Wilbur Wright Lecture.**—In reply to several inquiries, we have pleasure in stating that the account of the proceedings given in these columns is the verbatim report taken by the official shorthand writer of this Society.

### The Frontispiece.

The Frontispiece to this number is a photograph of the platform group in the Central Hall, Westminster, June 25th, 1918, on the occasion of the "Wilbur Wright Lecture." The names are as follows:—

*Back Row.*—Mr. Holt Thomas, Mr. A. E. Berriman, Mr. Griffith Brewer, Mr. Robinson (Secretary Air Ministry), Mr. Noel Smith, Dr. T. E. Stanton, F.R.S., Mr. Bramwell, Mr. Bairstow, F.R.S.

*Second Row.*—Brigadier-General Alexander, Mr. Handley Page, Sir Horace Darwin (Chairman Air Inventions Committee), Colonel O'Gorman, Mr. White Smith,

(Chairman Society of British Aircraft Constructors), Brigadier-General Ellington. Dr. Walmsley.

*Front Row.*—Mr. W. Barnard Faraday (Secretary), Dr. A. P. Thurston, Brigadier General Lord Montague of Beaulieu, Major Baird, M.P. (Under Secretary of State Air Ministry), General R. M. Ruck (Chairman Royal Aeronautical Society), Sir W. Weir (Secretary of State Air Ministry), Dr. W. F. Durand (Chairman of National Advisory Committee of United States).

It is to be greatly regretted that owing to the angle at which the camera was placed, that General Ruck is concealed from view to the left of Sir Wm. Weir.

# COMPRESSIBLE FLUIDS.

BY PROF. G. H. BRYAN, F.R.S.

(*Exclusive to* THE AËRONAUTICAL JOURNAL.)

The average orthodox mathematician who writes or reads books about hydrodynamics is so keen about getting a peg on which he can hang what he calls examples that he quite forgets to apply his formulæ to compressible fluids. It appeared to me on reading Colonel De Villamil's letter that a useful purpose would be served by writing the present note; it contains nothing but what anyone could write out for himself, but it was only recently that I made the attempt myself and I should be surprised if many readers have seen the same thing before. We know that in the irrotational motion of an incompressible fluid the velocity potential satisfies Laplace's equation, the present object is to find the corresponding equation for a compressible fluid, to grind it out at full length, and (what is more important than grinding it out) to interpret the result.

In the first place the property remains that if a velocity potential once exists for a particular mass of fluid, it will always exist provided that the following conditions are satisfied:—(*a*) That the impressed forces are derivable from a potential; (*b*) that the pressure is a function of the density only. The latter condition is, of course, not satisfied when water is being boiled or air is unequally heated. If $\phi$ is the velocity potential we have

$$u = d\phi/dx,\ v = d\phi/dy,\ w = d\phi/dz. \quad . \quad . \quad . \quad . \quad (1)$$

In the second place the pressure equation is

$$\int \frac{dp}{\rho} + V + \frac{d\phi}{dt} + \frac{2}{q^2} = \text{constant} \quad . \quad . \quad . \quad . \quad (2)$$

the first member taking the place of $p/\rho$ for an incompressible fluid.

In the case of a gas satisfying Boyle's Law, $p$ is proportional to $\rho$ and the integral becomes log $p$ or log $\rho$ plus a corresponding constant. If the velocity $q$ becomes infinite this gives log $p$ and log $\rho = -\infty$, whence $p$ and $\rho$ simply vanish instead of $p$ becoming negative. This is rather important because it shows that the motion need not necessarily become discontinuous in flow round a projecting edge or corner. If the edge is perfectly sharp there would have to be a vacuum at the edge. In other respects, however great the velocity anywhere, the pressure and density remain positive. Mind, I am only speaking of the interpretation of the equations.

If, however, the gas satisfies the adiabatic law $\rho = k\rho^{\gamma}$ where $\gamma > 1$ then

$$\int \frac{d\rho}{\rho} = \frac{\gamma}{\gamma - 1} k\rho^{\gamma - 1} + \text{const.} = \frac{V}{\gamma - 1} \frac{p}{\rho} + \text{const.}$$

and since $\rho$ can never be negative there is a limit to the velocity, determined by the conditions of the problem such as pressure on the boundary. In such cases

(and these are more important from a practical point of view than those in which Boyle's Law holds good) discontinuous motion or eddy formation is bound to occur when the fluid flows round a sharp edge.

Thirdly, the equation of continuity can be written

$$\frac{d\phi}{dt} + u\frac{d\phi}{dx} + v\frac{d\phi}{dy} + w\frac{d\phi}{dz} + \rho\left(\frac{du}{dx} + \frac{dv}{dy} + \frac{dw}{dz}\right) = 0 \quad . \quad . \quad (3)$$

So much for the text-books. The point of this note (if it has one at all) is that on substituting from (1), (2) and (3) we get an equation which when written in full becomes

$$\frac{d^2\phi}{dx^2} + \frac{d^2\phi}{dy^2} + \frac{d^2\phi}{dz^2}$$

$$= \frac{d\rho}{dp}\left[\frac{dV}{dt} + \frac{d\phi}{dx}\frac{dV}{dx} + \frac{d\phi}{dy}\frac{dV}{dy} + \frac{d\phi}{dz}\frac{dV}{dz}\right.$$

$$+ \frac{d^2\phi}{dt^2} + 2\left\{\frac{d\phi}{dx}\frac{d^2\phi}{dx\,dt} + \frac{d\phi}{dy}\frac{d^2\phi}{dy\,dt} + \frac{d\phi}{dz}\frac{d^2\phi}{dz\,dt}\right\}$$

$$+ \left(\frac{d\phi}{dx}\right)^2\frac{d^2\phi}{dx^2} + \left(\frac{d\phi}{dy}\right)^2\frac{d^2\phi}{dy^2} + \left(\frac{d\phi}{dz}\right)^2\frac{d^2\phi}{dz^2}$$

$$\left. + 2\frac{d\phi}{dx}\frac{d\phi}{dy}\frac{d^2\phi}{dx\,dy} + 2\frac{d\phi}{dy}\frac{d\phi}{dz}\frac{d^2\phi}{dy\,dz} + 2\frac{d\phi}{dz}\frac{d\phi}{dx}\frac{d^2\phi}{dz\,dx}\right]$$

In this equation we notice the following points:—

(1) Writing $dp/d\rho = a^2$, then $a$ is the velocity of sound waves, indeed under the conditions commonly assumed in the study of acoustics the equation reduces (by neglecting suitable quantities) to the well-known form

$$\frac{d^2\phi}{dx^2} + \frac{d^2\phi}{dy^2} + \frac{d^2\phi}{dz^2} = \frac{d\rho}{dp}\frac{d^2\phi}{dt^2} = \frac{1}{a^2}\frac{d^2\phi}{dt^2}$$

(2) It thus follows that the right hand portion becomes of importance when the velocity anywhere is comparable with the velocity of sound, and when this is the case the motion deviates to a corresponding extent from that of an incompressible fluid.

Now 60 miles an hour or 88 feet per second is just 8 per cent. of 1,100 feet per second, the value ordinarily given for the velocity of sound. As we have, however, to deal with velocities squared the divergence for an aeroplane going at this speed is not so great as would otherwise be the case. But at 150 miles an hour 8 is replaced by 20 per cent. and the velocity ratio squared is 4 per cent.

(3) The presence of the potential $V$ shows that the motion is not independent of the field of force. Of course this is so because, even if the fluid were at rest, the distribution of density would depend on the forces of the field.

(4) The presence of differential coefficients with respect to the time shows that the solution for steady motion does not (as in incompressible fluids) apply to unsteady motion.

(5) The equation is not linear in $\phi$, but the latter enters up to the third degree in the last two lines, thus showing that the solution depends generally on the rate of motion of the system, so that if one kind of motion has been worked out we shall not be able to satisfy the equation by supposing the velocities of all the parts to be increased or decreased in the same constant ratio. This, of course, makes the problem much more complicated than that of a compressible fluid as it is impossible in such a case as that of a solid moving in the fluid to do what we commonly do in some form or other in hydrodynamics, namely, assume an expression for the velocity potential with the velocity of the solid ($V$ say) written as a factor outside a bracket.

If I were wanting to solve a problem on the motion of a body in such a medium, I should employ approximate methods. I should first obtain a solution of $\Delta^2\phi = 0$ and call this $\phi_1$. I should then substitute $\phi_1$ for $\phi$ in the right hand side and find a new value $\phi_2$ of $\phi$ making $\Delta^2\phi_2$ equal to the result, and so on. I believe Mr. Robert Jones has done something of the kind. It ought not to be difficult in the case of a sphere or cylinder.

It is often recognised that as a matter of fact experiments in water lead to fairly consistent results when applied to the motion of bodies in air. At the same time, I consider that the effects of compressibility should always be kept in mind and that it is useful to think about the long equation we have written down for $\phi$ even if it be not used.

# THE DYNAMICS OF FLUID PROPULSION WITH SPECIAL REFERENCE TO THE PROBLEM OF THE AIRSCREW.

BY M. A. S. RIACH, ASSOC. INST. N.A., FELLOW.

(*Exclusive to* THE AËRONAUTICAL JOURNAL.)

In March of last year I had the privilege of reading a paper on the airscrew before the Society, "The Screw Propeller in Air."* The object of this paper was to extend what is usually known as the aerofoil theory of the airscrew, so as to include to some extent the phenomena of slip essential to propulsion in a fluid. This method has since, I believe, been fairly widely adopted both in experimental research work on airscrews and for purposes of designing and analysis.

The present contribution is the outcome of an attempt to modify the previous theory outlined in my paper, "The Screw Propeller in Air," which theory cannot be considered as being complete although at the time it was written nothing of a similar theoretical nature had been published with the exception of Mr. Lanchester's paper on "The Screw Propeller," this work being of a purely theoretical nature throughout and not directly based on model aerofoil data obtained from the wind channel.

The previous method of estimating the quantity of fluid, air in the case under consideration, dealt with by the propeller was to assume some constant fraction $f$ say of each annular ring element along the blade, the limiting possible value of $f$ being taken to be unity.

This method of estimating assumes that the speed of flow through any annulus is uniform around the circumference of such an annulus, or, if not, considers only a mean value for all portions of the circumference. Herein lies an error which may or may not be important, although I am inclined to think that the greatest difficulty really consists in obtaining an expression which shall correctly measure the quantity of fluid, in this case air, dealt with by each blade per second. In the previous theory, as enunciated in "The Screw Propeller in Air," this difficulty was avoided by assuming that the quantity of fluid passing through the screw per second could be measured by the area of the circle swept out by the diameter of the screw, as seen in plan, or by some constant fraction of this area. Thus, the measure of the quantity of fluid passing per second through any annular ring element at a distance of $x$ from the boss centre of the propeller could be expressed by $\rho \cdot f \cdot 2 \cdot \pi \cdot x \cdot dx \cdot (V + S/2)$, $V + S/2$ being the axial speed through the annulus relatively to the propeller.

At first sight perhaps there is not much fault to be found with this conception; it might well appear that if the total area involved in measuring the quantity of fluid passing through the screw disc per second is correctly represented by the area of the circle of which the propeller blades form the radii, the same argument must follow when applied to the individual ring elements or annulii composing the screw disc area. A moment's consideration will serve to show, however, that such is not necessarily the case, and that in fact we have logically no more right to assume that the area of any annulus is the true measure of the area involved for each radius than that the so-called "gap" or normal distance apart of the spiral paths of consecutive blades is the true depth of the layer of air dealt with

* Read before the Aeronautical Society on March 21, 1917.

by each element of blade. If we must assume some value for the depth of this layer, or more correctly "equivalent layer," of air (and eventually this becomes necessary if we are to arrive at correct quantitative results), then we have *a priori* no more right to assume that the "gap" measures the correct distance any more than any other value obtained empirically or otherwise.

Since therefore, by assuming the area of an annulus to be the correct area, we tacitly assume also that the depth of the equivalent layer is numerically equal to the distance apart of consecutive spiral blade paths, which cannot be considered as necessarily true *a priori*, it at once becomes evident that the whole conception of the annular ring area, as representing the area involved in the determination of the mass per second dealt with by the sum of the blade elements at any radius, may well be inherently false, with the result that the underlying basis upon which the theory is founded can no longer be regarded as representing in a proportionate degree the truth.

Having then got rid of the idea of the annular area or path gap area, which is the same thing ultimately, as being the correct measure of what we may call, for want of a better word, the "equivalent area" of fluid dealt with by any annular element, we are more at liberty to attempt to assess this value independently of such conceptions as those which form the basis of the previous treatment enunciated in my paper, "The Screw Propeller in Air."

There are other good reasons also which might be cited against the assessing of the equivalent area on the basis of path gap, which serve to show that such a conception is really entirely foreign to the aerofoil theory of the subject. Why, for instance, should the method of assessing in the respective cases of the aerofoil and the screw propeller (based on data obtained from aerofoils) be so fundamentally at variance as the adoption of the path gap hypothesis inevitably shows to be the case? There appears to be no good reason why this should be so, and in fact the whole analogy between the two cases is entirely opposed to such a view. The whole argument is really based on the introduction of an assumed condition possessing at first sight some appearance of truth, but ultimately under a more critical analysis serving only as a limitation and quite probable source of error.

When it becomes necessary to arrive at some estimate for this equivalent area, the easiest and probably also the most correct view to adopt in the present state of knowledge will be to again employ the analogy of the aerofoil which should so far as is known equally apply to the screw propeller.

The method adopted therefore in the present analysis will be to assess the performance of the airscrew upon the basis of some, for the moment, undefined value of the equivalent depth of air layer affected by any element of blade, and then quantitatively to allocate some value to such a depth either from theory or experiment.

It is probable that the final solution or approximate solution of the problem will be found in an extension of the theory of the subject based on vortex motion.

The final formula obtained in this way, connecting the lift coefficient of the section with the angle between the relative wind and the plane of rotation is concisely expressed by:—

$$Cy^1 = [2 \cdot \mu + Cx^1] \cdot \tan (A^1 - A)$$

where $\mu$ is the unknown factor to be determined either theoretically or from experiment. If no rational process of assessing the value of $\mu$ can be found, then we must abandon the whole theory as being incapable of representing the facts.

## APPENDIX.

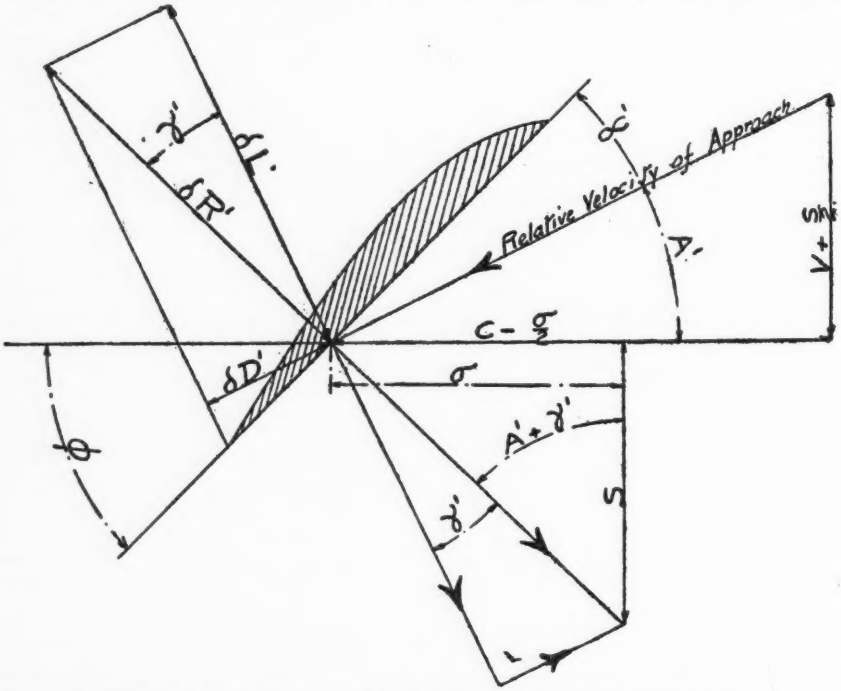
At a sufficient distance forward of the propeller disc where the fluid is undisturbed by the presence of the propeller the relative axial velocity between the fluid and the propeller is $V$. The fluid being set in motion by the action of the screw acquires after its passage through the screw disc, an added axial velocity $S$ and hence a relative velocity of $V+S$ with respect to the propeller.

In the same way a transverse velocity $\sigma$ is imparted in the plane of rotation of the propeller, the relative transverse speed between any blade element and the air after passing through the screw disc being therefore $C-\sigma$, $C$ being the speed of the element due to its rotation about the boss centre.

The relative velocity between any element of blade and the fluid may be shown to have a mean value, both axially and transversely, between its initial and final velocities.*

Thus the relative axial speed at any blade element is $V+S/2$ and the relative transverse speed is $C-\sigma/2$.

Let $A^1$, Fig. 1, be the angle between the relative wind and the plane of rotation for any blade element, and let $\phi$ be the angle between the chord of the blade section at any radius and the plane of rotation. Then $\phi - A^1$ is the chord




angle of attack of the blade element to the relative wind, denoted by $\alpha^1$. Hence, if $\gamma^1$ be the gliding angle of the blade section, defined by the relation $\tan\gamma^1 = \text{drag/lift ratio}$, the resultant force $\delta R^1$ on the element of blade will lie at an angle of $90+\gamma^1$ degrees to the relative wind.

* "The Screw Propeller with Race Rotation," "Aeronautics," Sept. 19, 1917.

From the geometry of the figure it is obvious that :—

$$\sigma = S \,.\, \tan (A^1 + \gamma^1) \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$\sigma$ and $S$ being the components transverse and axial of the total wake velocity imparted.

Also from the figure :—

$$\frac{V + S/2}{C - \sigma/2} = \tan A^1 \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Eliminating $\sigma$ between (1) and (2) and making the substitution $V/C = \tan A$, we get :—

$$S = \frac{2 \,.\, C \,.\, [\tan A^1 - \tan A]}{1 + \tan A^1 \,.\, \tan (A^1 + \gamma^1)} \quad . \quad . \quad . \quad . \quad (3)$$

Now the components of $\delta R^1$ are $\delta L^1$ and $\delta D^1$, the lift and drag forces on the blade element. Hence, writing these in the usual form :—

$$\delta L^1 = Cy^1 \,.\, \rho \,.\, b \,.\, dx \,.\, (V + S/2)^2 \,.\, \text{cosec}^2 A^1 \quad . \quad . \quad . \quad (4)$$

and

$$\frac{\delta D^1}{\delta L^1} = \tan \gamma^1 = \frac{Cx^1}{Cy^1} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

$Cy^1$ and $Cx^1$ being the absolute lift and drag coefficients of the blade section, $b$ the chord blade width at a radius of $x$, and $\delta x$ the radial increment, $b \,.\, \delta x$ thus being the value of the element of area of the section.

Then the net force axially on the blade element is :—

$$\delta T^1 = \delta L^1 \,.\, \cos A^1 \,.\, [1 - \tan A^1 \,.\, \tan \gamma^1] \quad . \quad . \quad . \quad (6)$$

and substituting for $\delta L^1$ from (4), we get :—

$$\delta T^1 = Cy^1 \,.\, \rho \,.\, b \,.\, dx \,.\, (V + S/2)^2 \,.\, \text{cosec}^2 A^1 \,.\, \cos A^1 \,.\, [1 - \tan A^1 \,.\, \tan \gamma^1] \quad (7)$$

and this expression measures the axial thrust per element per blade.

We now require to determine the quantity of air affected by each element of blade. Call the "equivalent depth" of air layer affected by any element of blade $\Omega$, so that for $N$ blades the total depth will be $N \,.\, \Omega$ for any annulus. Let $\mu = \Omega/b$. Then total mass per second dealt with by $N$ blades for any annulus will be :—

$$\rho \,.\, dx \,.\, N \,.\, \mu \,.\, b \,.\, (V + S/2) \,.\, \text{cosec } A^1 \quad . \quad . \quad . \quad (8)$$

and therefore total thrust per annulus due to $N$ blades is :—

$$N \,.\, \delta T^1 = \rho \,.\, \delta x \,.\, N \,.\, \mu \,.\, b \,.\, (V + S/2) \,.\, \text{cosec } A^1 \,.\, S \quad . \quad . \quad (9)$$

By equating (9) to (7), we get :—

$$Cy^1 = \frac{\mu \,.\, S \,.\, \tan A^1}{(V + S/2) \,.\, [1 - \tan A^1 \,.\, \tan \gamma^1]} \quad . \quad . \quad . \quad (10)$$

Now from (3) :—

$$\frac{S}{V + S/2} = \frac{2 \,.\, [\tan A^1 - \tan A]}{\tan A^1 \,.\, [1 + \tan A \,.\, \tan (A^1 + \gamma^1)]}$$

Hence, substituting in (10):—

$$Cy^1 = \frac{2 \cdot \mu \cdot [\tan A^1 - \tan A]}{1 + \tan A \cdot \tan A^1 - \tan \gamma^1 \cdot [\tan A^1 - \tan A]} \quad . \quad . \quad (11)$$

Now put $\tan \gamma^1 = Cx^1/Cy^1$, and finally we obtain:—

$$Cy^1 = [2 \cdot \mu + Cx^1] \cdot \tan (A^1 - A) \quad . \quad . \quad . \quad . \quad (12)$$

This constitutes the fundamental relation between the momentum and aerofoil theories as originally outlined in my paper, "The Screw Propeller in Air." The unknown quantity in the above equation is $\mu$, and if we adopt the older process of assessing the equivalent depth of air layer on a basis of "path gap," $\mu$ will have a value of:—

$$\frac{2 \cdot \pi \cdot x \cdot \sin A^1}{N \cdot b} \cdot \left[\frac{1 + \tan A \cdot \tan (A^1 + \gamma^1)}{1 + \tan A^1 \cdot \tan (A^1 + \gamma^1)}\right],$$

that is, that $\mu$ becomes a function of $x$ and $A^1$. For the reasons already given, however, it appears that the value of $\mu$ cannot be correctly assessed upon this hypothesis, and without further theoretical evidence the problem is one which demands an experimental solution. It is quite possible, however, that further light will be thrown upon the subject from theoretical considerations. Supposing that we have some process by which the value of $\mu$ can be correctly arrived at, the method of employing equation (12) in practice is quite simple. For purposes of analysing any existing type of airscrew, $Cy^1$ is plotted graphically against $\alpha^1 = \phi - A^1$, $\phi$ being known for all radii chosen. Superimposing the wind channel curve for the section considered will then give values of $Cy^1$ and $Cx^1$ and $\alpha^1$, *i.e.*, $A^1$, for any radius $x$ considered. It is then merely necessary to substitute such values in the equations for torque, thrust and efficiency (given below) to determine the values of the same under any conditions.

The axial thrust *per blade* is given by:—

$$\frac{dT^1}{dx} = 4 \cdot \pi^2 \cdot n^2 \cdot \rho \cdot x^2 \cdot Cy^1 \cdot b \cdot \sec A^1 \cdot [1 - \tan A^1 \cdot \tan \gamma^1] \cdot \frac{[1 + \tan A \cdot \tan (A^1 + \gamma^1)]^2}{[1 + \tan A^1 \cdot \tan (A^1 + \gamma^1)]^2}$$

The transverse thrust *per blade* $= dT^1 \cdot \tan (A^1 + \gamma^1)$ and the efficiency

$$\eta^1 = \frac{V}{2 \cdot \pi \cdot n \cdot} \cdot \frac{\int dT^1 \cdot}{\int dR^1 \cdot x}$$

as given previously in "The Screw Propeller with Race Rotation."*

Conversely, in designing an airscrew for any given conditions, the same formula is employed, the process being either graphical or analytical depending upon the basis upon which the value of $\mu$ is assessed.

* "Aeronautics," Sept. 19, 1917.

# THE RESISTANCE TO TORSION OF WOODS.

The only experiments on the resistance to torsion of woods that I have been able to find are those of Benjamin Bevan, in the " Philosophical Transactions " of 1829, p. 127. As these may interest the members of the Aëronautical Society I give below a list of his results. I have, however, taken the liberty of substituting my own records for the average weights per cubic foot, as Bevan gives but few, and these to my mind are unsatisfactory, being the result of single trials, whereas mine are the mean of series of tests collected from all sources. I have then re-arranged the list according to these weights in order to test Bevan's suggestion that " the modulus of torsion bears a near relation to the weight of the wood." Certainly the higher results are found amongst the heavier woods; there are, however, a few exceptions that render a blind confidence in this rule somewhat dangerous and it should be accepted as a rough guide only. I regard it more as a demonstration of the very general fact that, apart from freaks of structure, heavy woods are *in all respects* stronger than light woods.

In the second place I have classified the woods according to their moduli, the species being arranged in groups corresponding with each increment of 5,000lbs.

| Name of wood. | Average weight per cu. ft. in lbs. | Torsion lbs. |
|---|---|---|
| Brazil ... ... | 65½ | 37,800 |
| Boxwood ... ... | 63½ | 30,000 |
| African Teak ... | 63¼ | 27,300 |
| Satinwood ... ... | 59¾ | 30,000 |
| Lancewood ... ... | 57½ | 25,245 |
| Holly ... ... ... | 54 | 20,542 |
| Plum ... ... ... | 51¼ | 23,700 |
| Damson ... ... | — | 23,500 |
| Hornbeam ... ... | 50¾ | 26,411 |
| Elder ... ... ... | 49¼ | 22,285 |
| Beech ... ... ... | 48½ | 21,243 |
| Pear ... ... ... | 48 | 18,115 |
| Crab ... ... ... | 47½ | 22,738 |
| Laburnum ... ... | 47 | 18,000 |
| Ash ... ... ... | 46½ | 20,300 |
| Apple ... ... ... | 45½ | 20,397 |
| Teak ... ... ... | 45½ | 16,800 |
| Oak (according to variety) ... ... | 44 | 12,000 to 20,000 |
| Acacia (Robinia) ... | 44 | 28,293 |
| Elm ... ... ... | 43½ | 13,500 |
| Mountain Ash ... | 42 | 13,933 |
| Cherry ... ... | 40¾ | 22,800 |
| Hazel ... ... ... | 40 | 26,325 |
| Birch ... ... ... | 39½ | 17,250 |
| Chestnut (Sweet) ... | 39¼ | 18,360 |
| Walnut ... ... | 39 | 19,784 |
| Sycamore ... ... | 39 | 22,900 |
| Plane ... ... ... | 36¼ | 17,617 |
| Pine (according to variety) ... ... | 35¼ | 10,500 to 14,750 |
| Scots Fir ... ... | 35¼ | 13,700 |
| Larch ... ... ... | 35 | 18,967 |
| Horse Chestnut ... | 34¾ | 22,205 |
| Alder ... ... ... | 33¾ | 16,221 |
| Scented Cedar ... | — | 12,500 |
| (if Havana) ... | 33½ | — |
| Lime ... ... ... | 31 | 18,309 |
| Ozier ... ... ... | — | 18,700 |
| Sallow... ... ... | — | 18,600 |
| (Willow, Salix alba?) | 29½ | — |
| Deal ... ... ... | — | 11,220 |
| Spruce ... ... | 28½ | — |
| Poplar ... ... | — | 9,473 |
| Black Poplar? ... | 28½ | — |
| Cane ... ... ... | — | 21,500 |

Bevan's list rearranged by groups corresponding to increments of 5,000 torsion lbs. :—

| | |
|---|---|
| Under 10,000 lbs. ... ... ... | Poplar. |
| Above 10,000 and under 15,000 lbs. | Oak (variety), Elm, Mountain Ash, Pine, Deal, Scots Fir, Scented Cedar. |
| ,, 15,000 ,, 20,000 ,, | Pear, Laburnum, Teak, Birch, Chestnut, Walnut, Plane, Larch, Alder, Lime, Osier, Sallow, Oak (variety). |
| ,, 20,000 ,, 25,000 ,, | Holly, Plum, Damson, Elder, Beech, Crab, Ash, Apple, Cherry, Sycamore, Horse Chestnut, Cane. |
| ,, 25,000 ,, 30,000 ,, | African Teak, Lancewood, Hornbeam, Acacia, Hazel. |
| ,, 30,000 ,, 35,000 ,, | Boxwood, Satinwood. |
| ,, 35,000 ... ... ... ... | Brazil. |

From these two tables we may conclude:—

(*a*) That resistance to torsion does not correspond with transverse strength as we find the oak, the scented cedar and the pine grouped together.

(*b*) That it does not go along with elasticity as the laburnum, a highly elastic wood, is grouped with the lime and the willow. The laburnum as a bow-wood is superior to the hazel and is heavier, but it here works out at only about two-thirds of the torsion strength. Again, it is curious to find the crab apple and the cane together, a very odd pair.

(*c*) That it does not accord with flexibility, as the notoriously flexible beech falls in with the horse chestnut and the apple, which certainly are not.

(*d*) That it does not show any agreement in point of structure, as in this respect all the groups are of a very mixed character.

If any conclusion can be drawn in addition to that suggested by Bevan, it is that fissile woods are the least resistant to torsion as the whole of the group under 15,000lbs. are fissile and it is well known that a stick split by twisting will separate much as had it been cleft. Hence, we may say that the heavier woods should be preferred as being the most resistant to torsion providing that they are not fissile. In practice it is, however, as easy and more sure to make a torsion test than one for fissibility, indeed the former may serve for both. It should not be assumed that because a wood splits straight that it also splits easily. The oak is commonly rent in the direction of its radius for cask staves, panels and plasterers' laths, because it cleaves with a more or less even surface, but it is really more fissile in the direction of the annual rings. The mulberry, also used for cask staves, has no large rays (silver grain) and hence is sawn tangentially to the rings. The hazel is split for barrel hoops, yet it comes close after the acacia in Bevan's list and it cannot be called a fissile wood.

It seems to me that we are still short of important details. We need to know through what angle the various woods twisted before they ceded, as it seems obvious that the cane would twist very much more than the beech although their moduli of torsion are very near each other (21,500 and 21,243 respectively).

Some of the results are surprising. We find the much despised horse chestnut wood to be superior to the oak, the ash, the teak and the elm; the last named species being unexpectedly low. By the way, I must point out that the horse chestnut, though showing such a remarkable resistance to torsion for so light a wood, is hardly suitable for aeroplanes as it absorbs moisture from the air more than any other species recorded. General experience is also against this wood and one is inclined to suspect an error in Bevan's list; the horse chestnut seems

10,000lbs. too high. Empirically, the tables may afford a few hints, for example, the brazil, that heads the list, is exceedingly heavy but not twice as heavy as the pine, while its resistance to torsion approaches three times that of the best variety of that wood tested by Bevan. If I understand the needs of aeroplane construction rightly, a stiff wood is preferable to one that yie'ds too readily, providing that it will support the same stress. A momentary stress once passed, the brazil would whip back into its primitive form much more quickly than the pine. As brazil is now little used for dyeing purposes, it should be abundant and not too dear. As in comparison with pine, only two-thirds of the weight and less than two-thirds of the bulk will be necessary, a substantial gain in two directions is possible, and when we consider that brazil is the classical wood for violin bows, its merits will be appreciated in spite of its place at the heavy end of the series.

The pick of the whole list is, however, the acacia (Robinia), and that for many reasons. It comes fourth for resistance to torsion and eighteenth for weight. It is very abundant in France and Italy, especially in small sizes, and it has merit of being of better quality when of second growth, *i.e.*, coppice, in which manner it is chiefly cultivated to fix the soil of railway embankments. It is the favourite wood of the French wheelwrights and its strength is so great that loads are put on two wheels at Marseilles such as we should hardly dare to put upon four. In point of carrying power, the two-wheeled camion of Provence made of acacia, is a never-failing wonder to me.

There is a great opportunity for anyone having access to the necessary apparatus and material to clear up disputed points in respect to both torsion and fissibility. A research properly carried out would be a real service not only to aeroplane construction but to science generally.

HERBERT STONE.

Lyons, July 6th, 1918.

# ABSTRACTS.

## 300 h.p. De Haviland Aeroplane.

This article explains in great detail the construction of the D.H. 4, 300 h.p. Rolls-Royce, giving the exact dimensions and materials of most of the parts. Particular attention is drawn to the system of dual control, which, it maintains, is a feature of all English two-seaters.

Photographs of the machine in various positions are given and detailed drawings of the wing fuselage body structure and the contour of the wing section. ("Deutsche Luftfahrer Zeitschrift," June 22, 1918.)

## German Aeroplanes.

This article consists in essence of a series of very good photographs of the following German machines, showing in most cases not merely the general build, but the detailed external construction of many parts.

Fokker monoplane.
Fokker biplanes, D.1, D.2, D.3, D.4, D.5.
Fokker triplane, D.R.I.
Rumpler biplane, G.
L.V.G., C.IV.
Albatros, D., C.10, C.III., G.
Ago, C.I., C.4.
Gotha, G.2.
Aviatik, C.III.
L.F.G., C.II., D.I.
Friedrichshafen, G.II.
D.F.W., C.V.
Siemens, D.I.
A.E.G., C.I., G.3.
Halberstadt, D.

Some of these photographs are so clear and accurate that the main dimensions of the machines can easily be determined. ("Motor," May-June, 1918.)

## Air Propulsion.

This paper describes experiments with propellers, asserting that the accepted screw theory of air propulsion does not accord with the facts and should be replaced by a theory of reflection or batting action which explains the fact, experimentally established, that air is impelled by a propeller at a speed approaching twice the screw advance for small-blade angles. Thrust is shown to be due in greater degree to velocity and less to blade disc area than is commonly supposed. A method of predicting the complete flying performance of a propeller from a single static test of a model is indicated.

According to the current theory, it is stated, air is driven by a propeller with a velocity never exceeding the product of the propeller's pitch and its revolutions. It was a surprise therefore to find experimentally that air may be driven back at a velocity nearly twice as great as this product indicates. This "super-speed" effect is not generally noticed in the ordinary propeller owing to the mingling of high-speed air with a quantity of inert air lying between the propeller blades. Experiments were made on a propeller having very wide blades sweeping the entire 360° of disc area. It had an experimental mean pitch of 2.53 ft., and gave a wind on static test of 3.33 ft. per revolution, regardless of the rotational speed of the propeller. The super-speed ratio, 3.33/2.52, is 1.32. It is explained by the theory that the particles of air are driven back by precise reflection or batting action from the blade surface. The geometry of the motion is given for static and wind tunnel or flying conditions, and it is shown that the super-speed ratio is in each case given by $2 \cos^2 a$ where $a$ is the angle which the blade makes with the 'plane of rotation. This factor varies from nearly 2 for low-pitch angles found near the blade-tip to 1 for a 45° angle. Normal values for super-speed would lie usually

between 1.5 and 1.6. In the case of the propeller, which has been cited, the calculated super-speed ratio comes out as 1.31, as against the experimental value, 1.32. Similar close agreement was found by other confirmatory tests.

Investigation of the air-flow from a static propeller by means of light ribbons showed that the air moves in a direction strictly perpendicular to the blade angle, the condition demanded by the reflection theory, but not by screw action. Further, the ribbons indicated that the stream contracts slightly as it leaves the propeller, whereas " with the squeezing action of a screw it would be expected that the air would be expanding rather than contracting."

An experiment giving a convincing demonstration of super-speed is described, in which two propellers are tested in tandem in a wind tunnel. With the forward propeller or blower giving a wind of 44 ft./sec. and the rear propeller driven at just over idling speed (revs. × pitch equal to 48 ft./sec.), an anemometer showed a wind speed behind the rear propeller of 50 ft./sec. Shutting down the blower while keeping the revolutions of the rear propeller constant caused the wind speed to rise to 75 ft./sec., instead of remaining constant as demanded by the screw theory.

The proper interpretation of super-speed should render it possible to predict the flying performance of a propeller from static tests. The following formula is given as a preliminary empirical approximation :—

$$T = T_0 - T_0'$$

where T is the flying thrust at forward speed V and revs. $n$.

$T_0$ is the static thrust at revolutions $n$.

$T_0'$ is the static thrust at propeller speed $V/p$ where $p$ is the propeller pitch.

That is, $T_0'$ is taken statically at what is idling speed in the wind. Since static thrust varies as $n^2$, a single static thrust at any speed enable both $T_0$ and $T_0'$ to be derived. With this formula the flying thrust at 30 per cent. slip is found to be 51 per cent. of the static thrust at speed $n$. (Morgan Brookes, " Aviation," New York, June 1, 1918.)

**Calculation of Stresses in Aeroplanes.**

FUSELAGE STRESSES.

The analysis of the wind forces acting on a fuselage of the girder type and the resulting distribution of stresses in the members is carried through in a particular case. The tail portions of the fuselage are regarded as constituting a cantilever projecting from the centre of support, and the maximum normal wind forces on the tail 'plane and elevator are estimated from a knowledge of the angle of inclination of each part, its dimension and the maximum wind speed of the machine. These forces are based on Eiffel's formula :—

$$P = 0.0033\ AV^2$$

where P = Normal pressure in lbs./sq. ft.

A = Area of surface in sq. ft.

V = Velocity of wind in miles/hour.

These wind forces, in addition to the weights of the various members, are assumed distributed among the top junctions of the vertical struts with the longerons, half the load being borne by each vertical face, the horizontal and vertical sides not interfering. The stresses are calculated by two methods: (1) Graphically, by an application of Bow's Notation in the usual manner; (2) analytically, by equating the sum of the external moments about a junction to the left of a vertical section through a member to the moment of the face in that member. By choosing a number of suitable points about which to take moments all the forces may be found.

The dimensions of the wooden members are then checked by using the formula:

$$\frac{P}{A} = \frac{b}{l+c}\left(\frac{l}{k}\right)^2$$

where P = Breaking load in lbs.
A = Area of cross-section in sq. ins.
$l$ = Length in inches.
$k$ = Least radius of gyration in inches.

$b$ and $c$ being constants such that:—

For spruce $b = 5{,}600$
For ash $b = 6{,}250$

$c$ depends on $l/k$ according to the table.

| $l/k$. | Value of $l/c$. Spruce. | Ash. |
|---|---|---|
| 60 | 11,000 | 10,000 |
| 80 | 10,000 | 9,000 |
| 120 | 8,000 | 7,000 |
| 160 | 6,500 | 5,000 |
| 200 | 5,000 | 4,000 |
| 240 | 4,000 | 3,000 |
| 280 | — | 2,800 |

(S. E. Slocum, "Aerial Age Weekly," June 10, 1918.)

**Electric Dynamometer.**

A description is given of the general method of testing an aero engine by means of an electric dynamometer, whose power is absorbed either by external electric resistances, or by pumping current against the pressure in the mains. The various points which have to be watched both in the apparatus itself and in the working of it are considered. The operation of a typical control panel for a 400 h.p. electric cradle dynamometer is described and a cut of the panel given.

The close and accurate readings possible with electric dynamometers have saved many a new engine on its first test by giving a timely warning of impending trouble. When making a long run at a given speed, the operator should watch his scales closely. If the torque and speed drop off and do not come back again the engine requires attention. ("Aviation," New York, June 1, 1918.)

**Swiss Aeroplane Sheds.**

An advertisement by the Hetzer Wood Construction Co., Zurich, showing elevations and sections of aeroplane sheds at the Swiss Government Flying Ground at Dubendorf. The construction is entirely of wood, and the design is patented. The firm states that they have built sheds already covering an area of about 160,000 sq. metres. ("Schweizerische Bauzeitung," July 13, 1918.)

**The General Movements of the Atmosphere.**

The atmosphere is subject to certain general movements which extend over periods more or less prolonged and proceed in definitely ascertained directions. These movements comprise wide zones of activity. The charts prepared by the Signal Office at Washington embrace the whole hemisphere, and show that the areas of high and low pressure, which characterise during each season the general air-circulation, undergo displacements and transformations that exert influences alternately in opposite directions, and produce effects duly recorded in the different Meteorological Offices.

The complexity of these movements and the frequent changes in their duration render their general study a matter of extreme difficulty, but the author has found it possible, by treating each chart as an instantaneous photograph, and by providing the necessary intermediate points to prepare cinematograph films which give a record of these movements and indicate the various phases. Numbers of these charts have been connected together in this way, and the high pressure areas have been rendered more visible by colouring them of a grey tint. By this means he has already produced three cinematographic films, the first of which comprises the surface of Europe and Asia, and shows that this mode of attacking the problem is possible, but that "the phenomena" are here a little complicated by the presence of two neighbouring maximum areas over Siberia and the Azores. In the case of the other two films, the one of Europe and the other of North America, the results are very clear. It becomes evident that in a general way the depressions that occur in succession, first towards the North on the 60th parallel, and then to the South on the 30th parallel, swag in such a manner that their trajectory rises and falls alternately, and that the atmosphere over the region thus examined undergoes a species of respiratory action, with alternate elevation and depression. Some of the features of this phenomena are explained, and the modes of interpreting them are discussed. As the outcome of his studies, the author maintains that the formation of the storm periods can be foretold with great certainty, as they follow very definite laws. Both the sun and moon have great influence upon the atmosphere, as already shown by M. Poincaré, and the moon, in the vicinity of the 30th parallel, controls the movements of vast regions of the atmosphere. It becomes possible by the plan above described to predict the condition of the atmosphere on any given meridian and to deduce the probable weather for the course of the day with the changes brought about by high or low atmospheric pressure at any selected point. ("Comptes Rendus," July 22, 1918.)

**Vincent-Multiplex Compass.**

This is a description of the Vincent-Multiplex compass, which it is claimed combines within a small box all instruments necessary to the aviator, the navigator and the explorer for the determination of the magnetic declination and for the solution of astronomical, geodetic and topographical problems required for determining position and directing the course of travel. It is further claimed that the problem of steering craft overseas and in the air may be solved with a precision hitherto unknown.

The improved compass is furnished with the usual accessories. There are provided a reference line or directrix under a glass plate which may be rotated, a movable index card with sights for the measurement of angles and azimuths, and a style for the solution of time problems. The whole compass is suspended on gimbals inside a box which is pivoted on a slab. The box carries on one of its faces a needle and a dial, and on its bottom a second needle which moves over degree graduations on the slab.

The method of using the compass over sea and land is described. ("L'Aerophile," May, 1918.)

**French Avion-Renault Biplane.**

This is a description of the French A.R. (Avion-Renault) biplane. It is stated that this machine presents the following characteristics:—

*Wing Members.*—Upper wing, continuous span 13.32 m.; lower wing, upward dihedral 16 cm., sweep back 10 cm., span 13.25 m. Depth of wing in both cases, 2.02 m. Perpendicular distance separating wings 2 m.; for each centre of forward spar was 30 cm. from leading edge, and centre of rear spar 82 cm. forward of trailing edge. Ribs, 33 cm. apart. Upper wing given backward stagger 54 cm. measured close to body; this offers clear upward field

of view to the pilot; the observer is placed, it is said, exceptionally far back; but the upper wing is cut away just above, and the lower wing cut centrally to a semi-circle as far as the rear spar. Total wing area 44.75 m², exclusive of flaps. Two pairs outer struts and two inner pairs, the latter reinforced and sewing to support the body. Four additional steel members are introduced below to take up the propeller thrust. All struts of wood, streamlined to 120/38 mm. at the centre, and 90/28 mm. at the extremities. Ailerons attached to rear spar of upper wing, extending on either side from tip as far as line of inner struts.

*Body.*—Forward section approximately square, 800 mm. broad, with slightly cambered top-side; tapering back, and supporting a rudder-post of height 500 mm. Total body length 8 m.

It is pointed out that no appreciable additional damping area is added. The reputation of the machine in regard to longitudinal stability is attributed to wing section. Elevator area 4.2 m².

*Engine, etc.*—Water-cooled, 8-cylinder, in V formation. Four magnetos, allowing of double ignition, each magneto operating in 4 cylinders. Main petrol 180 l. capacity, auxiliary tank 8 l. Main aluminium radiator fitted to body nose connected to subsidiary cooler below the body.

*Armament.*—Observer's machine gun; pilot's machine gun operating through propeller; four small bombs.

Weight unloaded given as 894 kg. Useful load 300 kg., including crew of two, armament with ammunition and photographic apparatus. Fuel carried, 138 kg. petrol, 22 kg. oil, with 32 kg. cooling water; this gives total load 1,386 kg., leading to specific wing loading 29 kg./m², on the assumption that one half of the aileron area contributes to support.

No figures are available for speed and climbing performances. ("Oesterreichische Flug-Zeitschrift," No. 7-8, April, 1918.)

**Acrobatic Flying.**

A personal claim that "stunt" or acrobatic flying increases the confidence and enthusiasm of an airman introduces a list of different "stunts" in vogue at present; a diagram of each is given, together with instructions for performing them.

The ordinary loop and a series of loops are first dealt with, and it is pointed out that loops should be made when going into the wind. Two ways of getting into and out of tail spins are described.

The Immelmann Turn is next shown—the aeroplane performs half a spin about its axis when taking the loop, thus flying in its initial direction at the top. The "Upside Down Glide" (also shown) is very similar to the Immelmann Turn, the difference being that before regaining its original attitude it glides some distance upside down. Greater success will be obtained if the glide is made against the wind.

The "Barrel or Roll Over" also commences in the same way as the Immelmann Turn, but on the aeroplane reaching the top of its path, the operations are reversed, and the machine spins through 180° about its axis, its attitude remaining the same at the end of the "stunt" as it was at its commencement in the loop.

Finally the Reverse Loop is shown. It starts in the same way as the loop, but at the commencement of the descent from the top the aeroplane spins about an axis perpendicular to its length (*i.e.*, yawed) through 180°, thus enabling the pilot on completing his manœuvre to fly in a direction opposite to his original direction. (Lieut. C. W. Keene, "Aerial Age," June 24, 1918.)

**Motion of the Air through the Airscrew.**

The investigation is based on a diagram of the slip stream of a four-bladed pusher airscrew given by C. Schmid in the " Zeitschrift f. Flugtechnik u. Motorluftschiffahrt," 1915. This diagram gives the magnitude and direction of the velocity of the air at points in six planes perpendicular to the axis of the airscrew, three on either side of the airscrew. The velocity vectors are resolved into two components, axial and radial, the former (parallel to the airscrew axis) being assumed to be constant for any particular one of the six planes. The observations in the neighbourhood of the boss, and on the edge of the slip stream, are neglected.

The origin of co-ordinates is taken at the centre of the boss, and the positive direction of the $x$ axis is on the intake side. If $P$ be the force due to the rotation of the airscrew acting on a mass $m$ of the air, $c$ the velocity in any plane, $x$=constant (the suffix $s$ denoting the value at $x=0$), and $E$ the kinetic energy of the mass $m$, then

$$P = -\frac{dE}{dx} = mk\frac{c^2}{2_g} = \frac{KE}{g} \text{ whence } \log\frac{c}{c_s} = -\frac{k_x}{2_g}$$

or if $D$ be the diameter of the slipstream,

$$\log\frac{D_s}{D} = -\frac{K}{4_g}x \quad . \quad . \quad . \quad . \quad . \quad (a)$$

since $c_sD_s^2 = cD^2$

where $K$ is a quantity defined as the " viscosity factor " of the air. A table gives at each point at which observations were taken the value of $K$ calculated from the slipstream diagram by means of the equation ($a$). A mean value $K_m$ of $K$ is taken for each of the six planes, and final mean value is obtained by plotting $xKm$ against $x$ and taking the slope of the curve. The values given are 25.4 and 48.9 for the wake and intake sides respectively. (H. Bandisch, " Oesterreichische Flug-Zeitschrift," Nos. 9-10, May, 1918.)

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## CORRESPONDENCE.

*To the Editor of* THE AËRONAUTICAL JOURNAL.

SIR,—I see in the July number of the Journal that Mr. Pannell considers that whether the "function" in Lord Rayleigh's formula is upside down, or not, is of no importance. Is not this rather a quibble on the meaning of the word "function"? As Dini says, up to comparatively recently, "the expression function served exclusively for the denotation of the powers of one and the same quantity."

At present, however, the word is being employed to express *any kind of relationship*.

In this sense, I must admit that Mr. Pannell has some grounds for his assertion. I am therefore prepared to admit, for the sake of argument, that it is immaterial whether you say that "John is the grandfather—or the grandson—of James." It is all a matter of sign.

$$\pm \text{ grandfather} = \mp \text{ grandson.}$$

The "function" is the same.

In the case under discussion, however, the "function" is essentially a "power" of $(v/vl)$.

Since Mr. Pannell denies this, and says that I am "definitely wrong in this statement," I can only suppose (without wishing to be rude) that he does not understand how this equation is arrived at.

It is quite easy to decide this question; and as this formula is regularly employed by many people for, what I call, "mathematical window dressing," a short explanation will, I trust, be permissible.

Routh ("Rigid Dynamics") shows the "method of using the Theory of Dimensions *to predict a formula*."

Adopting the notation of Sir J. Larmor ("Ency. Britt.," *Dimensions*), and wishing to find the equation for fluid resistance, in terms of $(\rho)$ density, $(L)$ space, $(V)$ velocity, and $(\nu)$ *kinematical* viscosity, we may put

$$[M]^1\,[L]^1\,[T]^{-2} = [\rho]^x\,[L]^y\,[V]^z\,[\nu]^n.$$

Where, on one side of the equation, "force" has, 1 dimension in mass, 1 in space, and $-2$ in time. On the other side, $\rho$, $L$, $V$ and $\nu$ have dimensions which are to be found.

Since the dimensions, *in space, mass and time*, must be equal on both sides of the equation, it is easy to show that

$$\text{Resistance} = [\rho]^1\,[L]^{2-n}\,[V]^{2-n}\,[\nu]^n$$

$$\text{or } R = \rho\,(LV)^{2-n}\,\nu^n.$$

The equation, in this form, is very fashionable for "window dressing."

It will be seen, at a glance, that this is the same thing as

$$R = \rho L^2 V^2 \left(\frac{\nu}{VL}\right)^n.$$

which is exactly what I stated.

We do not know what $n$ is at present. A little reflection will show, however, that if there is *no viscosity*, there being no dimensions in $\nu$, $n=0$; and the equation then becomes

$$R=\rho L^2V^2 \text{ (Newton).}$$

If there *is* viscosity, we know from experiment that the resistance *caused by the viscosity* is *independent of the density of the fluid; n* therefore will, necessarily, $=1$, and the formula becomes

$$R = \mu LV \text{ (Stokes' Law).}$$

Again, since *part* of the resistance is due to the viscosity, and *part* to the density, the complete formula will be

$$R = \rho L^2V^2\left\{\frac{\nu}{VL} + 1\right\},$$

omitting any constant coefficients.

I must most emphatically deny Mr. Pannell's statement that I showed that this formula was *inapplicable to the resistance of fine wires*. On the contrary I showed that if $VL=1/200$, $(\nu/VL=0.1)$, the error caused by neglecting viscosity might be 10 *per cent.*; with smaller values of $VL$ it might greatly exceed this.

Since Mr. Pannell (like most people) employs the formula $R=\rho l^2v^2$, it is clear that he, whether he is aware of it or not, *implicitly* admits that the resistance *due to viscosity*—which I stated was generally "ridiculously unimportant"—is *negligible*. In any case, he has no $\mu$ or $\nu$ in his formula!

I observe, with regret, that Mr. Pannell carefully avoids referring to the difference between the resistance of a body in a fluid when the motion is *accelerated*, and when it is *uniform*. He quite overlooks—or, he may be unaware of—what is commonly called the "added mass." In accelerated motion, his equation should be

$$R=\rho l^2v^2\,(1\pm Q),$$

where $Q$ represents "the added mass"; the sign being $+$, or $-1$, according to whether the acceleration is positive or negative.

Dubuat* first pointed out the necessity for the "added mass," late in the eighteenth century.

Forty years later Bessel came across it again (whether from Dubuat's work or not I do not know—it may have been independently), and he, I fancy, did not understand it any more than Dubuat did.

In 1842 Duchemin published the fact once more. He, apparently, thoroughly understood it; though he does not explain *why* it should be added, nor give any proof.

Later, Poisson gave a *mathematical proof* for the case of spheres falling in water, where the acceleration was *positive*. This proof is given in Lecornu's "Cours de Mécanique."

In 1848 Sir George Stokes stated the facts, gave Poisson's formula for the resistance of spheres falling in water, besides giving Dubuat the credit for having been the first to point out the necessity for the "added mass."

Thousands of years before Dubuat, however, the bird found this out, and so

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* Dubuat is quite forgotten now. Even M.M. Eiffel and Lecornu *do not spell his name correctly*. In the B. Museum Catalogue, the works of Colonel Dubuat, Génie Royal, Capt. Dubuat, Génie Royal, and Count du Buat de Sassignies are all mixed up, as if they were by one author: yet the first wrote on Hydraulics, the second on Mechanics, whilst the third was a diplomat, and wrote on Political Economy.

learned how easy it was to "sail." He, certainly, has given no mathematical proof of the fact, but he has been giving daily demonstrations of it ever since.

If a gun is fired vertically, the resistance experienced by the shot when *ascending,* and at any given instant of time *when the speed is v,* say, is *less* than it is at the instant when it is *descending, at the same speed v.*

Some of this may not be known to most English readers, since it is not referred to in English text books. It should be learned, however, for as Colonel O'Gorman said in his Wilbur Wright lecture, "There is possibly more prejudice than proof at the root of our neglect to found any hopes on soaring flight."

In conclusion, might I request, as a favour, that I be allowed to correct the proofs of this letter. The printers have reduced some of the remarks I made to Mr. Pannell's lecture to quite unintelligible jargon; and such a long time has elapsed since last November that I cannot remember now *exactly* what I did say.

It is generally advisable, in an argument, to know what you are talking about.

Yours faithfully,

R. DE VILLAMIL.

August 18th, 1918.

# ABRIDGMENTS OF RECENT PATENT SPECIFICATIONS (AERONAUTICS).

COMPILED BY MR. H. T. P. GEE, PATENT AGENT.

116,269. G. Caproni, 28, Via S. Gregorio, Milan, Italy. April 20, 1918. Convention date, May 23, 1917. Not yet accepted.

**Planes, Arrangement of; Cars; Framework; Land Wheels.**—Aeroplanes, particularly biplanes having two fuselages, are constructed so that the fuselages, wings, and landing carriage may be dismounted from the central cell of the planes. In one form two fuselages carrying the engines are secured to the cell by bolts and stirrups and the wings are attached by means of extensions entering sockets and secured therein by bolts. Lateral stability of the landing carriages, when the wings are detached, is ensured by struts which are attached to the cell by the stirrups. The car is mounted on the lower plane.

**Propelling; Heating.**—The engine radiators are mounted in front of and below their respective engines in the two fuselages, and another radiator is placed at the front of the car and may serve to heat the car, being for this purpose fitted with adjustable dampers or apertures for regulating the temperature.

116,301. T. O. Perry, 324, Euclid Avenue, Oak Park, Illinois, U.S.A. December 11, 1916.

**Aerial Machines without Aerostats; Steering and Balancing.**—In helicopters having two superposed propellers driven in opposite directions, the pitch of the blades of one propeller may be adjusted in the same sense as that of the blades of the other for varying the lift, or in the opposite sense for causing a rotation of the car and of the forward propelling means for steering, and the blades of each propeller may be feathered to provide the forward propelling effort.

**Propelling.**—The motor drives a pinion which drives shafts in the same direction through gear wheels, and further shafts in the opposite direction by means of further gearing. A hand crank and pinion provided for starting the motor may be used to rotate the propellers by hand.

**Cars; Land Wheels.**—The car of circular form surrounds a central housing for the motor, and is fitted with two wheels and a single castor wheel.

116,338. W. F. Williams, Leadwood, Missouri, U.S.A. June 5, 1917.

**Aerial Machines with or without Aerostats; Planes, Construction of; Aerostats.**—An aeroplane has the wing and tail portions divided by partitions into a number of cells, which may be filled with compressed air or lighter gas by means of filling plugs. The central forward portion is open underneath and arched to form an inverted channel, and is formed with a front extension and an upwardly extending pocket. The entire periphery of the supporting surface is sharpened off.

**Cars.**—The car is hung from the plane by rods.

**Parachutes** are fitted, and comprise folding side portions, connected by links to runners movable on rods by means of levers and a hand lever, the initial opening of the parachute being assisted by springs. The sides are connected together by flexible end sections.

116,363. C. L. Pashley and A. H. D. Pashley, 27, Badminton Road, Balham, London. June 12, 1917.

**Alighting Indicators.**—A device for indicating to an aviator his proximity to the ground comprises a pendent pivoted arm adapted to contact with the ground and actuate through Bowden mechanism an indicating device in accordance with the angular position of the arm. An arm is pivoted between two walls carried on a turntable which is pivoted about a vertical pin to a bracket secured to the wheel axle. The arm is normally retained in position by a rubber spring. A Bowden wire is connected to a lug on the arm and is drawn around a segmental track on one of the walls as the arm is moved backwards. The other end of the wire is connected to a sliding member, adapted to be pulled down behind a graduated face against the action of a spring. This member may be illuminated.

116,364. H. R. Ritchie, 116, Deacon Road, Kingston-on-Thames. June 12, 1917.

**Steering and Balancing.**—In aeroplanes in which the tail surfaces are rotated about a longitudinal axis for lateral balancing, the tail plane and elevator are carried by rings rotatable on other rings fixed to the body, the rotation being effected by connections to the rudder bar, which for this purpose is mounted to oscillate in a vertical plane, in addition to the usual fore-and-aft oscillation for controlling the rudder. According to the provisional specification, the elevator alone may be rotatably mounted.

116,460. C. H. O'Rourke, Hanford, Kings County, California. November 28, 1917.

**Aerial Machines without Aerostats; Cars and Cabins; Framework; Planes, Construction of.**—An aeroplane is constructed with the main plane of triangular form in plan and with the underside curved outwards from the body. The framework of the body comprises longitudinals converging to the front and rear, and connected together in the tail portion by cross pieces and curved braces, and in the front portion by cross pieces of the main plane, the outer ends of which are connected to side members and to further curved braces. The framework thus formed is covered with fabric, openings being left above the seats. Windows are also provided adjacent to the seats. The rear inner portion of the upper surface of the main plane is sloped downwards to meet the rear edge of the lower surface.

**Propelling.**—The propellers are driven by chain gearing from a shaft, which is driven by chain gearing from the engine.

**Steering and Balancing.**—A lever moved fore and aft to operate the elevator, carries a hand wheel for operating the rudder, which is carried by the elevator. Ailerons are operated by means of a foot bar.

116,463. A. Schmuker, 261, Gladstone Avenue, Wood Green, London. December 3, 1917.

**Screw Propellers.**—An aircraft propeller is constructed of superposed laminæ, formed of pairs of half-length laminæ having segmental projections adapted to abut to form full-length laminæ, the meeting surfaces of superposed laminæ forming imbricated joints. The segmental projections are shaped so that a central passage for the boss is provided when the parts are assembled. The laminæ are glued together and may be secured additionally by annular discs fitting in grooves in the outer laminæ held in position by bolts passed through holes. The superposed segmental projections of the laminæ may be shaped to form a barrelled boss and the meeting faces may be bevelled.

116,893. J. F. Kahl, 161, Prospect Place, Brooklyn, New York, U.S.A. June 11, 1918, No. 9,590. Convention date, June 12, 1917. Not yet accepted.

**Aerial Machines without Aerostats; Cars; Framework; Planes, Construction of.**—An aeroplane adapted to alight on land or water comprises a body fitted with planes and with front and rear hulls carrying skids. The framework of the body and planes is covered with wire netting and aluminium or other metal. The upper surface of the planes is convex upwards from front to rear, and the lower surface is nearly straight. The tips of the planes are curved downwards. The front hull is provided with a flooring and with portholes to serve as a cabin, and a pilot house is provided.

**Floats, Arrangement of; Skids.**—Front and rear hulls serve as floats and are fitted with skids of laminated wood, etc. Floats and skids may be fitted also at the tips of the planes.

**Steering.**—A pair of forward rudders act in conjunction with a rear rudder.

116,907. W. S. Howell, Pleasantville, New York, U.S.A. April 5, 1917.

**Planes, Construction and Arrangement of.**—The lateral stability of aeroplanes or other aeronautical machines is enhanced by the use of small stabilising surfaces, fixed at opposite sides of the machine, for example, near the elevator, and arranged so that they diverge upwardly and converge towards the front of the machine. In one form two lateral surfaces are fixed to an elevator and inclined outwardly; they may be inclined inwardly or be vertical. In another form the stabilising surfaces are incorporated with the elevator, which is of curved cross section tapering to a smaller diameter at the front edge.

116,914. J. D. Roots, 58, Avonmore Road, West Kensington, London. June 19, 1917.

**Aerial Machines without Aerostats; Propelling.**—A propelling apparatus for ornithopter machines comprises a pair of shafts rotated in opposite directions and each carrying an obliquely arranged disc rotating freely within a carrier to which the wing is secured. In one form two discs are mounted on shafts and rotate within carriers fixed to the wing spars. The two carriers are connected together by links, or each may be connected by a link to the frame of the machine. The shafts are rotated in opposite directions by wheels engaging a worm on the engine shaft. Several engines may be arranged behind one another with their shafts fore and aft and with a pair of wings in front and a pair behind each engine. Clutches may be provided between contiguous engines and on the wing shafts. The pair of wings at one end of an engine may be 90 or 180 degrees in advance of the pair at the other end. In a modification, the discs are formed with double flanges at their peripheries embracing single flanges on the carriers. Specification 6,418/09 is referred to.

**Steering and Balancing.**—The leading or other engine and wings may be bodily adjustable so as to alter the angles of incidence of the wings.

**Planes, Construction of.**—The rear portion of a wing is made flexible and may be composed of two or more strips of steel, arranged at intervals along the wing and covered with canvas, etc.

116,942. W. H. Kelly, 111, East 20th Street, Cheyenne, Wyoming, U.S.A. July 4, 1917.

**Aerial Machines without Aerostats; Planes, Construction of.**—A flying machine comprises a body to which are hinged concavo-convex flapping wings provided with rigid front edges curving rearwardly, the remainder of the wings being flexible. Wings comprising rigid front portions extend also along the inner

edge and are formed with hinging flaps and flexible portions of canvas, etc., reinforced by ribs. In a modification, the ribs are set more or less radially to the front edge of the wing. In one form the flexible portion comprises a series of thin plates secured to the front portion and connected together at the rear by pins and slots to allow for the curving of the wing when in action.

**Cars.**—A car may be suspended from the body, the engines and operating gear being mounted in the body and actuated by means of levers extending down to the car.

116,951. H. G. King, 67, Avenue Road, Itchen, Hampshire. July 12, 1917.

**Planes, Arrangement of.**—The body of a flying boat has a truncated end from which extend two converging booms carrying a post for supporting the tail planes. The plane is connected to the body by struts and to the post by ties. The booms are secured in fittings and are braced by a tie.

116,984. Blackburn Aeroplane and Motor Co., Olympia, and J. W. Copley, Wynberg, Fernville Avenue, Roundhay, both in Leeds. September 17, 1917.

**Framework.**—A device for the attachment of bracing wires, particularly in aircraft, comprises a sheet metal blank bent to form two approximately parallel limbs in which slots are formed to take a trunnion to which the bracing wire is secured, preferably by screwing through a hole at right angles to the axis of the trunnion. The trunnion has grooves engaging the outer ends of the slots to prevent splaying of the limbs and to prevent axial movement of the trunnion which is introduced through enlarged portions of the slots near the bent portion and slid into position. The bent portion may be made cylindrical and placed astride a pin on the structure, or it may be flat and secured by bolts. More than one pair of slots may be made in a single bent plate to take additional trunnions.

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"The Co-ordination of Scientific Publications." By Sir Robert Hadfield. London: The Faraday Society. 1918. Oct. pp. 29.

"The Flying Poilu." By Marcel Nadaud. Illus. London: Hodder and Stoughton. 1918. Oct. pp. 216. 7s. 6d.

"Calendar of the Imperial College of Science." London. 1918. 6d.

"Airfare." By Edgar C. Middleton. Constable. London. 1918. Oct. pp. 192. Illus. 3s. 6d.

"With the French Flying Corps." By Carroll Darra Winslow. London. 1918. Constable. Oct. pp. 190. 3s. 6d.

"Short Flights." By "Spin." London. 1918. Hodder and Stoughton. Oct. pp. 218. 5s.

"Fuselage Design." By Arthur W. Judge. London. 1918. Selwyn and Co. 3s.